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Geochemistry of the clay-bearing sedimentary rocks of Glen Torridon, Gale crater, Mars

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Abstract

We present the findings of the ChemCam instrument of the Curiosity rover in the clay-bearing terrains of Glen Torridon, Gale crater, Mars. We show that two compositionally-distinct types of bedrock (Mg-rich and K-rich) are present, and that both bear strong geochemical signatures of open-system alteration.

1. Introduction

One of the main goals of the Mars Science Laboratory (MSL) mission was to investigate the clay-to-sulfate mineralogical transition observed from orbit within the lower strata of Aeolis Mons, the sedimentary mound at the center of Gale crater [1,2]. After several years of exploration, the Curiosity rover reached the orbitally-identified "clay-bearing unit" in January 2019. This area is now referred to as Glen Torridon (GT) by the MSL team. Clay-bearing rocks have already been encountered along the rover traverse [3,4], but the stronger and more continuous spectral signatures observed from orbit in Glen Torridon may indicate that the clay minerals are more abundant or better exposed. Accordingly, the ongoing scientific campaign aims at determining the nature and abundance of the GT clay minerals, as well as their detailed geologic and geochemical settings. Here, we present the findings of the ChemCam instrument during the first few months of the campaign.

2. Dataset

ChemCam measures the chemical composition of targeted rocks and soils within a few meters of the rover using laser-induced breakdown spectroscopy (LIBS). Quantification of eight major rock-forming oxides (SiO_2, TiO_2, Al_2O_3, FeO_t, MgO, CaO, Na_2O and K_2O) is performed routinely based on the method described in [5]. Each ChemCam analysis consists of a raster of several points, and each point itself consists of 30 laser shots. This approach enables removal of contaminations from fracture fills and soils, by discarding the corresponding points. In addition, given the fine-grained nature of Gale rocks, averaging several points provides a reasonable bulk composition for each target. As of sol 2391 (~April 28th 2019), ChemCam has analyzed a total of 113 targets at Glen Torridon.

3. Results

The floor of Glen Torridon is made of at least four types of materials: (1) a "coherent" type of bedrock, which has a somewhat massive texture and tends to form large slabs; (2) a "rubbly" type bedrock, which is more fractured and forms smaller blocks than the coherent bedrock; (3) abundant pebbles and granules; (4) soil. We compare below the composition of these different materials based on ChemCam data (Fig. 1).

The *coherent bedrock* is characterized by an enrichment in MgO (~6 to 11 wt%) compared to the rubbly bedrock, and a slight anticorrelation between MgO and SiO_2, forming a possible mixing line toward a high-Mg/low-Si endmember. This endmember could be a Mg-rich phyllosilicate, sulfate or carbonate, although no bulk sulfur or carbon is detected. The *rubbly bedrock* is characterized by an enrichment in both K_2O (>1.5 wt%) and SiO_2 (>55 wt%). This may be indicative of an enrichment in K-feldspar in the sediment source, whether these K-feldspars are still present or have been altered. Most of the *pebbles* show a composition very similar to the rubbly bedrock, which is consistent with the observation that the rubbly bedrock tends to degrade into pebbles more easily than the coherent bedrock. Finally, the local soils have a composition very similar to previous soils and sand dunes encountered at Gale [6].

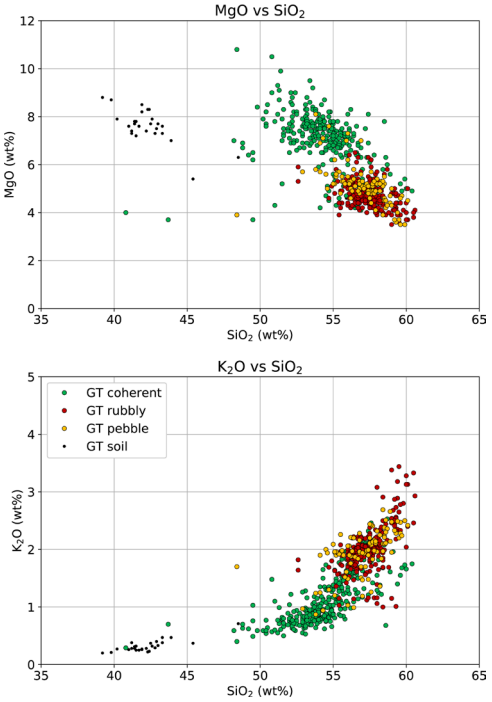

Figure 1: Major-oxide compositions of Glen Torridon rocks and soils. Each symbol corresponds to a single analysis point.

4. Discussion

Our results clearly show that two compositionally-distinct types of bedrock (Mg-rich and K-rich) exist at Glen Torridon. As mentioned above, the enrichment in Mg observed in the coherent bedrock is likely indicative of the presence of Mg-rich phyllosilicates, such as saponitic smectite. However, exposures of coherent bedrock are relatively scarce and thus lack the apparent continuity of the orbital signatures. On the other hand, the rubbly bedrock is more widespread in the area, and its degradation into pebbles may enhance absorption bands as seen from orbit. The K and Si enrichments measured in this material could be consistent with the presence of other clay minerals such as illite, although the orbital signatures are more consistent with smectites [7].

On a A-CN-K (Al_2O_3 – $CaO+Na_2O$ – K_2O) ternary diagram (Fig. 2), the compositions of GT rocks all fall above the plagioclase–K-felspar join, with values of CIA (Chemical Index of Alteration) on the high end of the range observed so far [8]. Therefore, both the coherent and rubbly types of bedrock show strong geochemical signatures – by Martian standards – of open-system weathering. This suggests that both types of materials (as well as the pebbles) may contain clay minerals and contribute to the orbital signal.

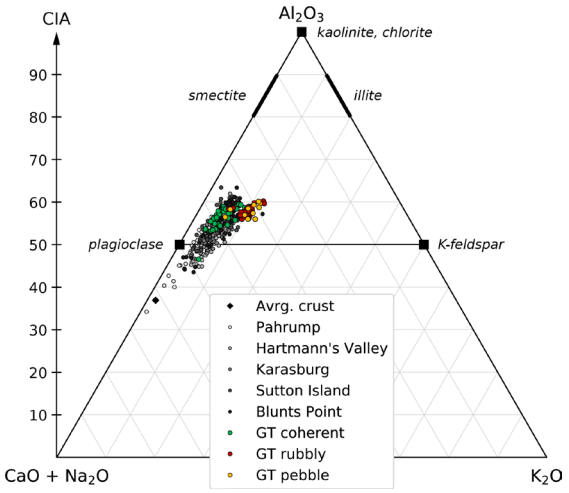

Figure 2: A-CN-K ternary diagram. Each symbol corresponds to a single target (average of 4 points or more). Data from other members of the Murray formation [8] are shown for comparison.

5. Summary and Conclusions

ChemCam data collected so far at Glen Torridon show the presence of two compositionally-distinct types of bedrock: a Mg-rich one, associated with a coherent, somewhat massive texture; and K-rich one, associated with a more rubbly texture. In addition, the latter type seems to be the source of (or at least is very similar in composition to) most pebbles in the area. Finally, the three types of rocks show strong geochemical evidence for aqueous alteration, suggesting that they could all contribute to some degree to the clay-mineral signature detected from orbit.

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